CAAP Quarterly Report

Date of Report: *July 15, 2019*

Contract Number: 693JK31850012CAAP

Prepared for: *USDOT Pipeline and Hazardous Materials Safety Administration (PHMSA)*

Project Title: *Magnet-assisted Fiber Optic Sensing for Internal and External Corrosion-induced Mass losses of Metal Pipelines under Operation Conditions*

Prepared by: *Missouri University of Science and Technology (Missouri S&T)*

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For quarterly period ending: *June 30, 2019*

Business and Activity Section

(a) Generated Commitments – Dr. Genda Chen directed the entire project and coordinated various project activities.

Mr. Liang Fan and Mr. Chuanrui Guo, two Ph.D. candidates in civil engineering at Missouri S&T, were on board since the beginning of this project. They are responsible for the fabrication and characterization test of sensors under Dr. Chen's supervision.

(b) Status Update of Past Quarter Activities – Detailed updates are provided below by task.

Task 1 Optimization of a magnet-assisted hybrid FBG/EFPI sensor enclosed in a plexiglass container for simultaneous measurement of temperature and pipe wall thickness

We numerically studied the effect of reduced thickness of a steel plate on the magnetic force generated on a hybrid FGB/EFPI sensor with magnets. The reduction of the steel plate is to simulate the process of corrosion on a steel pipeline.

When a steel plate is being corroded, it becomes thinner and has a reduced magnetic force from a nearby magnet. The reduced force causes the increase of the cavity between the optic fiber and the gold-coated glass, as shown in Fig 1. The interference spectrum of a hybrid FBG/EFPI sensor changes with the increase of the cavity, which is used to monitor the thickness change of the corroded steel plate. To assess the change of cavity length due to the magnetic force, ANSYS AIM 19.1 software with electromagnetic and structural modules was used to build a finite element model and run different cases of plate thickness. The steel plate has a dimension of 62 mm by 62 mm. The magnet is 6 mm thick and 62 mm in diameter. The air box has a dimension of 250 mm by 250 mm by 250 mm. The initial length of the spring between the steel plate and the magnet is 9 mm. The thickness of steel plate varies from 0.5 mm to 12.7 mm.

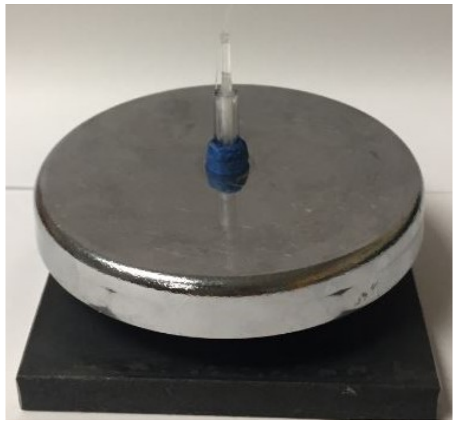


Figure 1. Assembling of a hybrid EFPI/FBG sensor and steel plate.

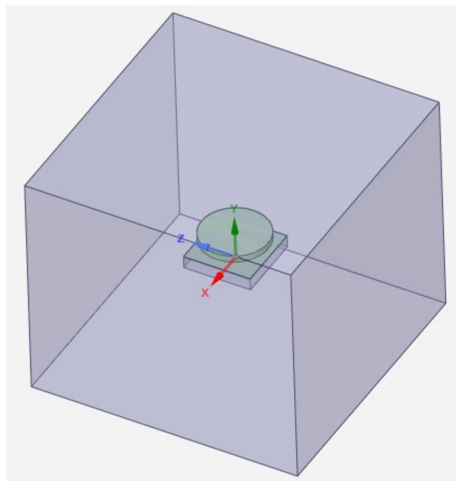
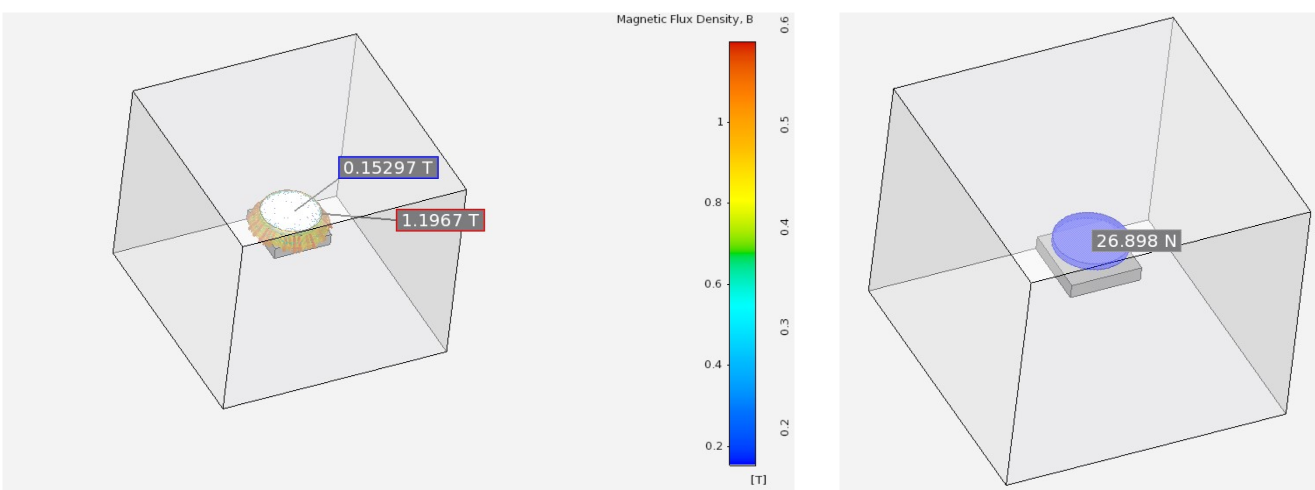


Fig 2. Geometry of the finite element model with a magnet and a steel plate enclosed by air.

Simulation results are presented in Fig 3 and Fig 4. Fig 3 shows the magnetic flux density and the magnetic force between the magnet and the 12.7 mm thick steel plate. Fig 4 indicates that the magnetic force has a parabolic changing trend with the increase of steel plate thickness.



(a) (b)

Fig 3. The magnetic flux density and the magnetic force between the magnet and the 12.7 mm thick steel plate.

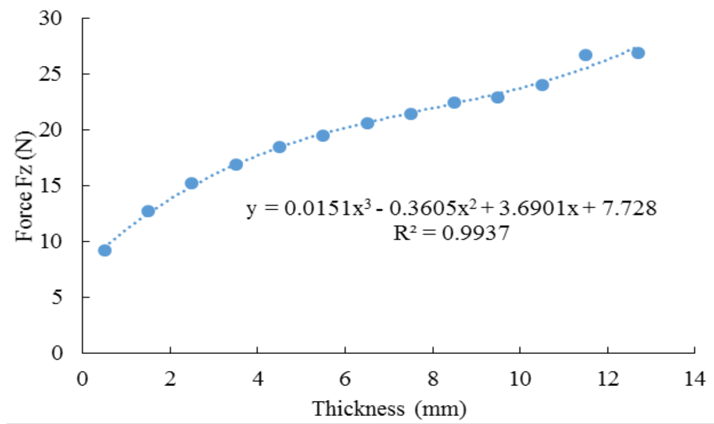


Fig 4. The mganetic force predicted by the FE model with a change of steel plate thickness.

With the known magnetic force, the cavity length can be calculated. Fig 5 shows the distance change between the magnet and the 12.7 mm thick steel plate. The change of cavity length equals to the relative distance change when the steel plate thickness is reduced. If the cavity length bewteen the hybrid EFPI/FBG sensor and the 12.7 mm thick steel plate is set to be the initial point, the cavity length change relative to the initial point with a gradual reduction of steel plate thickness is displayed in Fig 6. When the steel plate thickness reduces from 12.7 mm to 11.5 mm, the cavity length barely changes. After that, the cavity has a parabolic changing trend with the reduction of steel plate thickness. When the steel plate thickness reduces to 0.5 mm, the cavity change is the largest with the value of 0.73 mm.

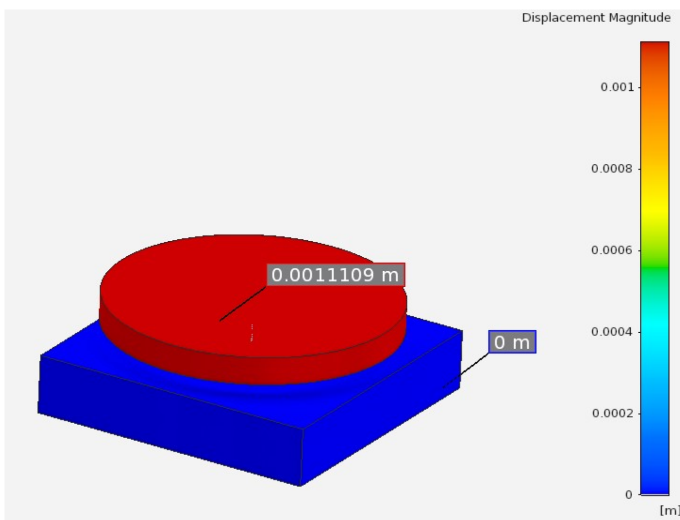


Fig 5. Distance change between the magnet and the 12.7 mm steel plate.

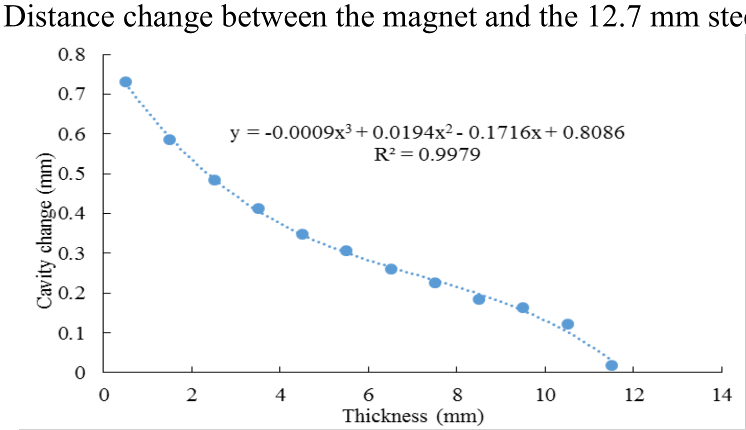


Fig 6. Cavity length change with the thinning of steel plate.

Task 2 Development and validation of a graphene-based LPFG sensor with Fe-C coating for improved sensitivity in mass loss measurement in varying temperature environment

This task will not start till the 4st quarter in 2019.

Task 3 Integration and field validation of multiple FBG/EFPI and multiplexed LPFG sensors for internal and external corrosion monitoring of a pipeline with temperature compensation.

This task will not start till the 2st quarter in 2020.

***(c)* Planned Activities for the Next Quarter** - The following activities in Task 1 will be executed during the next reporting quarter.

Task 1 Optimization of a magnet-assisted hybrid FBG/EFPI sensor enclosed in a plexiglass container for simultaneous measurement of temperature and pipe wall thickness

The magnet-assisted hybrid FBG/EFPI sensor will be used to monitor the thickness loss of a steel plate due to corrosion.

ANSYS will be used to simulate the effect of DC current applied to the steel plate on the magnetic force generated between the steel plate and the magnet. The effect of electromagnetic interference on the hybrid sensor due to DC current will be studied.